APPENDIX C

DITTON GEOTECHNICAL SERVICES REPORT

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Douglas Partners Pty Ltd

Worst-Case Mine Subsidence Assessment for the Proposed Minmi Subdivision, Link Road, Minmi

Report No. DPS-002/1

Date: 8 August 2008

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in association with:
Frith Consulting Pty Ltd and
Colwell Geotechnical Services

8th August, 2008

Mr Will Wright
Senior Associate
Douglas Partners Pty Ltd
15 Callistemon Close
Warabrook NSW 2310

Report No. DPS-002/1 DRAFT

Dear Will,

Subject: Worst-Case Mine Subsidence Assessment for the Proposed Residential Subdivision, Link Road, Minmi

This report has been prepared in accordance with the brief provided on the above project.

Please contact the undersigned if you have any questions regarding this matter.

For and on behalf of
Ditton Geotechnical Services Pty Ltd

Steven Ditton
Principal Engineer

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1.0 Introduction

This report provides predictions of worst-case subsidence, tilt, curvature, and strain contours across the proposed Minmi Residential Subdivision, Link Road, Minmi in the event of a pillar 'run' or widespread collapse of old mine workings in the Young Wallsend and Borehole Seams.

The site is located 10 m to 130 m above old Brown's Minmi/ Duckenfield Colliery's welsh bord and pillar workings in the Borehole Seam (circa pre-1950's) and old Wallsend Borehole and Gretley Colliery pillar extraction workings (circa post-1950's) in the Young Wallsend Seam. The Young Wallsend Seam is approximately 20 to 25 m above the Borehole Seam at this location.

The proposed development will consist of a 1 to 2 storey residential and commercial / retail buildings and associated infrastructure. Based on reference to **Appleyard, 2001** and **Mine Subsidence Board** correspondence for the project, these structures could be subject to potentially damaging tilts in excess of 4 mm/m, curvature radii of <10 km and strains of >2 mm/m if subsidence of more than 0.25 m was to develop at the site.

The purpose of the study was to define surface subsidence hazard zones for the subsequent definition of development restriction zones. The study was completed in two stages as follows:

Stage 1 - Preliminary worst-case subsidence contour predictions for exploration drilling planning, and

Stage 2 - Final worst-case subsidence predictions, based on the Stage 1 outcomes, and definition of subsidence impact hazard zones for the site.

The subsidence assessment has been based on reference to information provided in **Douglas Partners, 2008**.

2.0 Method

The study methodology included the following activities for Stages 1 and 2:

(i) Prediction of the respective subsidence contours for the site after all of the remnant pillars in the Borehole Seam and Young Wallsend Seam have ‘failed’ or crushed.

(ii) Prediction of the subsidence for the site due to the elastic compression of standing pillars and immediate roof and floor strata in partially extracted areas, first-workings areas and un-mined pillars in high extraction panels; and additional subsidence above goafed high extraction areas in the Borehole and Young Wallsend Seams due to ‘pillar run’ loading or goaf ‘re-activation’ events.

(iii) Estimate of future worst-case subsidence contours in each seam by subtracting the elastic subsidence from the fully crushed pillar or collapsed overburden (goaf) subsidence where appropriate. The contours were then added to develop the multiple-seam subsidence contours for both seams.

(iv) Determine the systematic tilt, curvature, and strain contours from the worst-case subsidence contours.

(v) Generate maximum tilt, curvature and strain hazard zones for subsequent building development constraint assessment.

(vi) Estimate Factors of Safety (FoS) of Zone 1, 2 and un-mined pillars in Zone 3 areas and define probability / likelihood zones of standing and collapsed pillars.

(vii) Repeat exercise (i) to (v) by assuming worst-case subsidence for pillars with FoS > 2.11 will be due to elastic compression from the full tributary area (FTA) acting on the pillar and > 1.6 for the case of single abutment loading along goaf edges.

(viii) Provide suggestions on the above mining zones in regards to further drilling investigations required to ascertain whether a panel is standing or already failed.

(ix) Review pillar geometry and subsidence prediction modelling assumptions, based on additional drilling investigations and adjust subsidence hazard zones as considered necessary.

The subsidence predictions were prepared based on the following:

(i) A review of the available mine workings information for the site provided by Douglas Partners and sourced from the Department of Primary Industries, Maitland.

(ii) A review of a report prepared by Brunskill Pty Ltd on the mine workings history and likely mining heights. A search for available mine subsidence data did not yield any information in the study area. A walk over inspection of the site was completed by a DP

Engineer and indicated that the surface had been subsided in places due to the presence of old cracks (refer to **DPS, 2008** for details).

(iii) The worst-case predictions were based the published **ACARP, 2003** database of subsidence above longwall panels and chain pillars in the Newcastle Coalfield. The maximum subsidence was then adjusted for bulking effects of remnant pillars and collapsed roof material and multiple seam effects as described in **Li *et al*, 2007, Zipf, 2005** and **Holt, 2001**.

Estimates of maximum subsidence, tilt, curvature and strain contours over the workings in both seams beneath the site were then determined using SPDS® software and **ACARP, 2003** model outcomes. The contours were developed from Autocad® plans of the workings outlines in each seam. The maximum potential subsidence contours for each seam were then superimposed to derive the combined seam subsidence contours.

(iv) Factor of Safety estimates for the pillars were estimated using the empirical models described in the **ACARP, 1998a** and **ACARP, 1998b** reports, and based on full tributary and side abutment load case scenarios were appropriate.

(v) Elastic compression of pillar/floor/roof under full tributary area load were based on analytical solid mechanics theories presented in **Das, 1998**.

(vi) Bearing capacity of floor and roof was based on empirical observations by **Pells, 1998** and shallow bearing capacity theories in **Das,1998**.

The outcomes of the subsidence contouring exercises described above are presented in the following sections.

3.0 Existing Conditions of Mine Workings

A review of record tracings for each of the mines, indicates that the workings in each seam may be sub-divided into the following zones:

Zone 1 - 'Low' extraction ratio first workings (15% to 45% of the coal extracted)

Zone 2 - 'Moderate' pillar extraction ratio second workings (50% to 72% of the coal extracted)

Zone 3 - 'High' pillar extraction ratio second workings (80% to 85% of coal extracted)

The above mine workings zones and cover depth contours for the Young Wallsend and Borehole Seams are presented in **Figures 1** and **2** respectively.

The Young Wallsend Seam (YWS) workings are predominately Zone 3 or 'High' pillar extraction ratio panels with a large proportion of the workings likely to have already collapsed roof or goaf. The panels are supercritical and separated by first workings pillars (Zone 1) with some Zone 2 areas around the peripheries. The average working height in the YWS panels was 2.4 m in the 2.9 m to 3.0 m thick seam. Approximately 0.5 m of shaley coal was left in the roof.

The Borehole Seam (BHS) workings are predominately Zone 2 or 'Moderate' pillar extraction ratio panels which could have remnant pillars that are still standing or have crushed out. The panels are separated by first workings pillars with some Zone 3 panels present below the eastern and western limits of the mining area. The average working height in the BHS panels ranged between 1.65 and 2.1 m in the 1.9 m to 2.3 m thick seam. Approximately 0.25 to 0.33 m of coal was left in the floor.

Based on discussions with ex-mine and land management representatives for the mines at Minmi, some areas of the Zone 2 workings in both seams have probably collapsed and some are still standing. Both seams generally dip towards the south west at about 2^o to 3^o and are partially flooded.

Mine washery tailings consisting of sand, silt and clay-sized particles were also pumped during mine operations into both of the seams from boreholes that were drilled down from the surface above the Duckenfield mine workings and from the YWS in the Gretley mine workings. The voids in the workings have only been partly filled with tailings and the location an extent of the backfill is unknown at this stage.

The Stage 2 drilling consisted of five cored boreholes to the BHS (Bore No.s 201, 202, 301, 302 and 305) where cover depths ranged from 58 to 77 m. The location of the bores is indicated on **Figures 1** and **2**.

The YWS was encountered at depths ranging from 37.5 m to 56.5 m with the following range of conditions in a 'High' extraction panel (Zone 3):

- 3 m of intact, full seam thickness coal;
- 1.09 m to 2.2 m of solid coal with 0.5 m to 1.1 m of overlying rubble; and
- 2.25 m of rubble (with no coal) overlain by 0.75 m of void.

The pillars in this area of the mine were formed on 24 m x 30 m centres with 5 m wide ‘splits’ driven through the pillars on retreat to leave irregular corner or intersection stooks to provide temporary support to the immediate roof. Soft, soil-like tailings were also encountered in Bores 201-202 but not in the bores to the north (301, 302 -305).

In the BHS, the bores encountered the following conditions in the ‘Moderate’ Extraction panels (Zone 2):

- 2.33 m of solid, full seam thickness coal;
- 0.25 to 0.33 of floor coal overlain by 0.73 to 2.05 m of void with 0.0 to 3.0 m of rubble .

The workings are welsh bords with an average 4 to 5 m wide x 31 to 38 m long pillars and 7 to 8 m wide bords and 3 m to 5 m wide cut-throughs (61% to 72% extraction ratio). The cover depth to the BHS workings is 58 and 76 m. No tailings were encountered and the water level was coincident with the roof of the seam.

The overburden and YWS / BHS interburden consists of thinly interbedded sandstone and siltstone (laminite) with moderate to high strength. The floor of the BHS is the Waratah Sandstone Member with high to very high strength (UCS >50 MPa)

The UCS of the laminate units ranges between 25 MPa and 60 MPa, based on point load and UCS testing of representative core samples. Some low to medium strength minor shale and coal seams exist in the immediate roof and floor of the workings and overburden, see **Figure 3**.

4.0 Stability of Pillar System

The worst-case subsidence that may develop beneath the Minmi site will depend upon (i) the long-term stability of the Zone 2 pillars that are still standing in the BHS workings and (ii) the degree of further goaf consolidation in the Zone 3 areas of both seams if the pillars mentioned above become unstable.

The stability of the pillars in the two seams below the site have been assessed based on consideration of the following key factors usually associated with long-term behaviour of pillar-roof-floor strata systems:

- Pillar load
- Pillar strength
- Bearing capacity of immediate roof and floor strata
- Multi-seam stress interaction effects
- Elastic properties of coal pillar-roof-floor strata system
- Deterioration effects

Each of the above items will be addressed in the following sub-sections.

4.1 Pillar Load

Based on the RT of the workings, the pillars beneath the site in Zones 1 to 3 exist in predominantly super-critical panel geometries (i.e. with panel width to cover depth (W/H) > 1.4) with some sub-critical panels. The stability of the pillars will depend primarily upon the cover depth, average pillar width and height for the panel and overburden / interburden thickness ratio (i.e. a multiple seam interaction factor).

Reference to **Zipf, 2005** indicates that if the overburden to interburden thickness ratio (O/I) for the site (which ranges from 1.7 to 6) is less than 7, then multi-seam pillar stress interaction is unlikely to occur.

Therefore, the pillars beneath the site are only likely to have full tributary area (FTA) load acting upon them in the upper and lower seams. A conceptual model of FTA conditions is shown in **Figure 4**.

The estimate of the total stress acting on the remnant pillars under full tributary area (FTA) loading conditions (i.e. the full column of rock above the pillar is supported by the pillar system). The total stress acting on the pillars after mining was estimated as follows:

σ_{pillar} = pillar load/area = T/w^2

where:

T = Full tributary area load of column of rock above each pillar;

= $(w+ r)^2.\rho.g.H$;

w = pillar width (solid);

r = roadway width;

H = depth of cover;

The Zone 1 and 2 Pillars in the overlying Wallsend Borehole Colliery Workings YWS, pillar stress ranges from to 0.72 MPa to 4.38 MPa. The Zone 3 Pillars in the YWS will have multi-abutment loads acting on them and pillar stress is estimated to range from 1.66 MPa to 36 MPa.

4.2 Worst-case Loading Conditions due to a Pillar Run

Worst-case conditions, due to a pillar run, will probably result in extra load being transferred to the pillars as the overburden above the failing pillars deflects. Underground stress and surface subsidence monitoring around super-critical width longwall panels in the Newcastle Coalfield (refer to **ACARP, 1998a** and **ACARP, 2003**) indicates that the additional load may be estimated based on an abutment or overbreak angle of 21^o.

The abutment-load limit line is drawn from the mid-point of the bord next to the pillar adjacent to the goaf at seam level to the surface; the concept is shown in **Figure 5**.

For a 5 m wide pillar with 8 m wide bords, the increased load/ m length (A) acting on the pillars adjacent to a collapsed area may be estimated as follows for 45 m to 120 m:

$A = 0.5\ u\ H^2 \tan(\theta)$ where u = unit weight of overburden (0.025 MPa/m)
θ = abutment angle (21^o)

$= 0.5\ (0.025)\ H^2 \tan\ (21^o)$

= 9.7 - 69 MN/m length of pillar adjacent to goaf

The equivalent average pillar stress in an panel could then be estimated by multiplying ‘A’ by the pillar length plus the bord width to derive the total load and then dividing it by the pillar area to arrive at the total stress increment. The abutment load is also concentrated closer to the rib side and distributed out from the rib-side based on the parabolic stress distribution profile presented in **ACARP, 1998a,** see **Figure 5**.

The proportion, R of the abutment load, A that will load a goaf edge pillar may be estimated using the formula presented in **ACARP, 1998a**:

$R = 1 - [(D-w-r)/D]^3$ where D = distance that load distribution will extend from goaf edge = 5.13 √H = 34 to 56 m (**Peng and Chiang, 1984**).
H = cover depth (m).
w = goaf edge pillar width or dimension normal to the goaf edge.
r = bord width on either side of the loaded pillar.

The outcome of this exercise indicates that approximately 70% of the abutment load will be applied to the first pillar adjacent to the goaf and result in average pillar stresses increasing the FTA stresses by 0.9 to 6.8 MPa.

4.3 Pillar Strength

The strength and stability of coal pillars has been the topic of interest for numerous rock mechanics researchers over the past 40 years since the South African Colbrook disaster in 1960, which involved violent, sudden failure of over 4,400 pillars in a matter of minutes (and 7,700 pillars over several hours), **ACARP, 2005**.

Based on the outcomes of this research, the Australian, South African and US mining industries have found that the most reliable way to estimate the strength of a coal pillar is to apply empirical methods and statistical analysis techniques within the bounds of experience. The most reliable empirical pillar strength formulae to-date have used the pillar width, pillar height and a database of ‘failed’ and ‘un-failed’ pillar cases to derive ‘calibrated’ pillar factor of safety (FoS) values. The FoS of a panel of pillars is the ratio of pillar strength/average pillar stress.

The pillar width/height ratio is also a very important factor that indicates the post-yield behaviour of the pillars when they are overloaded. The width to height ratio of the pillars in the database ranges from 0.87 to 12.

Pillars with w/h ratios < 3 are considered most likely to ‘strain-soften’ and result in rapid failure and pillar runs, whereas w/h ratios > 5 are more likely to ‘strain-harden’ and fail slowly or ‘squeeze’. These types of post-yield behaviour have been discussed in **ACARP, 2005** and demonstrated in **Figure 6** for various in-situ observations and laboratory experiments.

The pillars in the BHS workings have average width/height ratios ranging between 1.9 and 6.1 in the Zone 2 panels and between 2.4 and 9.7 in the Zone 1 panels for the maximum possible pillar height range of 2.1 m.

The pillars in the YWS workings have average width/height ratios ranging between 2.1 and 6.3 in the Zone 2 panels and between 2.1 and 10.4 in the Zone 1 panels for the maximum possible pillar height range of 3.0 m.

It is therefore possible that a pillar run could occur in the workings where slender pillars are still standing, and stop where ‘squat’ pillars are present.

The pillar strength formulae currently used in the Australian coal industry is based on a non-linear power law, which assumes that for an FoS of 1, the pillar panel will have a Probability of Failure (PoF) of 50%. The database of 177 cases includes 35% of 'failed' and 65% of 'un-failed' pillar panels from the SA and Australian Coal industries and is plotted in terms of pillar strength v. pillar load in **Figure 7a**. The pillars within the panels were all generally considered to be subject to full tributary area loading conditions, except for one failed case, which had several abutment loads applied to it from adjacent goaf development.

It is also apparent from the FoS lines drawn through the database in **Figure 7a**, that all of the failures occurred between FoS values of 0.74 and 1.62 and that there is a 'blurring' of failed and un-failed cases between an FoS range of 1.3 and 1.6.

Based on the database and reference to **ACARP, 1998b**, the strength of 'strain-softening' pillars, with width to height (w/h) ratios of < 5, may be estimated with the following non-linear power rule formula:

$S_p = 8.6w^{0.51}/h^{0.84}$ (MPa) where w = effective pillar width (m)
h = pillar height (m)

The length of the pillar (l) increases the effective width for w/h ratios > 3 and < 6 as follows:

$w_{eff} = [2\,l\,/\,(w+l)]^{(w/h\,-3)/3}$

For rectangular pillars with w/h < 3, the length of the pillar does not influence the strength.

The strength formula for 'squat' or strain hardening pillars with w/h ratios > 5, is as follows:

$S_p = 27.63\Theta^{0.51}(0.29((w/5h)^{2.5} - 1) + 1)/(w^{0.22}h^{0.11})$ (MPa)

where:

h = pillar height (m);

Θ = a dimensionless 'aspect ratio' factor or w/h ratio in this case.

4.4 Pillar Factor of Safety

The pillar FoS was then calculated by dividing the pillar strength, S_p, with the pillar stress, σ_{pillar} due to FTA loading. The applied pillar stress and strength for the range of pillar geometries in the YWS and BHS are presented in **Table 1**. Details of pillar FoS calculations are presented in **Appendix A**.

Table 1 - Summary of Pillar FoS Calculations for Existing Conditions in Mine Workings

Seam	Mine	Pillar Type Extraction Zone (refer to text)	Pillar Width (w)	Max Pillar Height (m)	Pillar Strength (MPa)	Panel Cover Depth Range (m)	Pillar FTA Stress (MPa)	Pillar FoS
YWS	Wallsend Borehole	1	8.7 - 12.5	3.0	9.2 - 33.7	20 - 120	0.72 - 4.38	29.3 - 4.2
		2	10.0 - 21.2	3.0	9.9 - 14.7	20 -110	0.83- 4.76	16.95 - 2.77
		3	12.5 - 43.7	3.0	11.3 - 36.1	20 - 115	0.74 - 4.49 (*8.55*)	25.48 - 2.55 (*1.34*)
	Gretley	1	6.3 - 31.2	3.0	7.8 - 21.1	30 - 110	1.41 - 4.80 (*19.5*)	9.77 - 1.62 (*0.40*)
		2	6.3 - 18.9	3.0	7.77 - 14.12	30 - 120	1.58 - 7.20 (*23.8*)	5.84 - 1.08 (*0.33*)
		3	7.5 - 37.5	3.0	8.52 - 28.28	30 - 120	1.07 - 6.48 (*35.7*)	20.8 - 1.31 (*0.26*)
BHS	Browns/ Duckenfield	1	5.1 - 20.4	2.1	9.4 - 24.7	30 - 150	1.1 - 8.1	18.7 - 1.42
		2	4.1 - 12.7	2.1	9.5 - 16.6	20 - 145	1.0 - 10.8	16.3 - 1.01
		3	-	2.1	-	-	-	-

YWS - Young Wallsend Seam
BHS - Borehole Seam
WBH - Wallsend Borehole Colliery Workings.
(*Italics*) - Single abutment load and FoS.

The pillar load and strength data for the YWS and BHS workings are also presented graphically in **Figures 7b, 7c** and **7d**. The outcome of the FoS analysis suggests that some of the pillars in each seam will be standing and some will have collapsed.

This observation concurs with the view of the mine representatives and the results of recent drilling by DPS, which encountered crushed out remnant pillars in the Zone 3 goaf areas in the YWS and standing pillars in a 72% Zone 2 extraction panel in the BHS, despite a calculated FoS value of 1.40 at 73 m depth of cover.

As previously discussed, the maximum future subsidence was determined for the following two pillar run cases in the Zone 2 areas of the BHS workings:

Case (i) - by ignoring the inherent stability of the remnant pillars after yield and assuming complete pillar crush will occur in all standing pillars in Zone 2 across the site, and

Case (ii) - by assuming the pillars will behave elastically in Zone 2 where the FoS values under FTA loading conditions are > 2.11 or >1.6 under abutment loading conditions along goaf edges.

The pillars in Zone 1 areas have been assumed to behave elastically for both of the above cases, as it is considered that this is both reasonable (due to their inherent stability of first workings pillars) and conservative (in terms of maximising potential tilts).

The unmined pillars in the Zone 3 panels are partially or fully surrounded by goaf and could be subject to multiple abutment loading conditions. The same logic has also been applied as was done for Zones 1 and 2 areas in assessing the stability of standing pillars in Zone 3.

Based on full tributary area loading theory (and ignoring multi-seam interaction effects) the cover depths above each of the Zone 1 and 2 pillar panels in the BHS and YWS workings where elastic pillar response would be likely to occur, have been estimated. The results are summarised in **Table 2**.

Table 2 - Pillar Extraction Zones and Estimated Cover Depth Limits for Elastic Behaviour (i.e. FoS > 2.11) under FTA Loading Conditions

Seam	**Mine**	**Pillar Type Extraction Zone** (refer to text)	**Pillar Extraction Ratio Range**	**Pillar w/h**	**Elastic Depth of Cover Limit* (m)**	**Panel Cover Depth Range (m)**
YWS	WBH	1	19 - 66%	2.9 - 12.5	343 - 60	20 - 120
		2	40 - 57%	3.3 - 7.1	116 - 75	20 - 110
		3	22 - 46%	4.2 - 14.6	NA	20 - 115
	Gretley	1	31 - 58%	2.1 - 10.4	221 - 54	30 - 110
		2	40 - 58%	2.1 - 6.3	134 - 54	30 - 120
		3	23 - 56%	2.5 - 12.5	NA	30 - 120
BHS	Browns/ Duckenfield	1	29 - **65%**	2.4 - 9.7	237 - **60**	30 - 150
		2	51 - **72%**	2.0 - 6.1	128 - **45**	20 - 145
		3	-	-	-	-

YWS - Young Wallsend Seam
BHS - Borehole Seam
WBH - Wallsend Borehole Colliery Workings.
* - Also satisfies FoS > 1.6 under single abutment loading conditions
NA- Elastic behaviour assumed under multiple abutment loading assumed if FoS > 1.6 (conservative).
Bold - Key extraction ratio and contour depths for Pillar Run Case (ii).

The FoS values used for elastic behaviour cut-off limits are considered conservative, based on the database of failed and unfailed pillar panels and the standing Zone2 area pillars in the BHS that were encountered in boreholes 301 and 302.

The above FoS values also consider the expected ‘strain-softening’ behaviour of the BHS pillars beneath the site, which is also a significant issue in regards to the consequences of pillar failure and potential risk to the proposed development structures.

4.5 Roof and Floor Bearing Capacity

Reference to **Pells *et al* , 1998** indicates that the bearing capacity of sedimentary rock under shallow footing type loading conditions is 3 to 5 times its UCS strength. Based on the estimated range of UCS values in the immediate floor and roof strata the general bearing capacity of the floor strata is estimated to range between 60 and 150 MPa.

A similar outcome is predicted by shallowing footing bearing capacity theory presented in **Das, 1998**.

For pillars with widths ranging from 4 to 25 m wide pillars and the average FTA pillar stress range of 1 to 11 MPa predicted (see **Table 1**), an overall average FoS against roof and floor bearing failure ranges between 5.45 and 13.6, which is highly likely to be within the elastic behaviour range.

Due to the absence of time-dependent subsidence observations above the flooded areas of the workings, it is also considered unlikely that long-term degradation or weakening of the roof/floor materials will be significant.

5.0 Future Worst-Case Subsidence Predictions

5.1 Maximum Panel Subsidence

In regards to Pillar Run Case (ii) and the Zone 1 and 2 panels, if the calculated FoS for the panels is < 2.11 under FTA loading or < 1.6 under single abutment loading conditions, the maximum panel subsidence has been estimated by multiplying the effective mining height of the pillars (T_e) and a subsidence factor (a) of 0.6. The effective mining height is determined based on **Salamon and Oravecz, 1976,** whereby the actual mining height is multiplied by the pillar extraction ratio.

Alternatively, if the calculated FoS for the panels is > 2.11 under FTA loading or > 1.6 under single abutment loading conditions, the maximum panel subsidence has been estimated by multiplying the minimum pillar subsidence due to elastic pillar system compression (see **Section 5.2**) by 5 (to provide a conservative factor of safety on the elastic parameters assumed).

For the Zone 3 panels in each seam (which have already goafed or partially collapsed) additional goaf reactivation or additional consolidation movements equal to 12.5% and 8% of the mining height has been estimated for the YWS and BHS respectively, based on reference to **Holt, 2001**.

For Pillar Run Case (i) predictions, the FoS values for the Zone 2 panels has been ignored to provide for the possibility that the dimensions of the pillars are incorrect and the pillar run goes right to the panel limits.

5.2 Minimum Panel Subsidence

The following equations derived from elastic solid mechanics theories have been applied to predict minimum pillar subsidence for super-critical panel geometries:

$s_{max} = s_{pillar} + s_{roof} + s_{floor}$

where

s_{pillar} = σ_{net} h/E_{coal} = compression of pillar

s_{roof} = σ_{net} w I(1-v^2)/E_{roof} = compression roof strata

s_{floor} = σ_{net} w I(1-v^2)/E_{floor} = compression of floor strata

σ_{net} = net pillar stress (FTA stress - virgin stress)

E_{coal} = Young's Modulus for coal = 2 GPa;

E_{roof} = Rock Mass Young's Modulus for the roof strata within one pillar width of the roof = 40% of 300 x UCS = 6 GPa;

E_{floor} = Rock Mass Young's Modulus for the floor strata with one pillar width of the floor = 40% of 300 x UCS = 6 GPa;

v = Poisson's Ratio = 0.25 for roof and floor strata;

I = shape factor for square footing = ~ 1 (for a semi-rigid footing)

w = pillar width.

h = pillar height.

Collapsed roof rubble adjacent to standing pillars will also provide load bearing capacity but only after significant subsidence has occurred (i.e. 10% of the seam thickness).

5.3 Results

The maximum future super-critical panel subsidence predictions for each seam's panel zones are presented in **Table 3**.

Table 3 - Predicted Worst-Case Subsidence above Supercritical Panel Geometries

Seam	**Mine**	**Pillar Zone** (refer to text)	**Max Pillar h (m)**	**Pillar Run Case (i) - Pillar Panel FoS in Zone 2 Areas Ignored**				**Pillar Run Case (ii) - Pillar Panel FoS > 2.11 Cover Depth Limits in Zone 2 Areas Included**			
				S_{max}/T	S_{min}/T	**Net S/T**	**Subs (m)**	S_{max}/T	S_{min}/T	**Net S/T**	**Subs (m)**
YW	WBH	1	3.0	0.002-0.12	0.000-0.003	0.002-0.010	0.005-0.03	0.002-0.12	0.000-0.003	0.002-0.010	0.005-0.029
		2	3.0	0.002-0.22	0.001-0.003	0.002-0.22	0.006-0.66	0.002-0.22	0.001-0.003	0.002-0.22	0.006-0.66
		3	2.4	0.125	0.000	0.125	0.30	0.125	0.000	0.125	0.30
	Gretley	1	3.0	0.006-0.31	0.001-0.004	0.005-0.30	0.01-0.91	0.006-0.31	0.001-0.004	0.005-0.30	0.01-0.91
		2	3.0	0.01-0.31	0.001-0.01	0.01-0.30	0.02-0.90	0.01-0.31	0.001-0.01	0.01-0.30	0.02-0.90
		3	2.4	0.125	0.000	0.125	0.3	0.125	0.000	0.125	0.3
BH	Browns/Ducken-field	1	2.1	0.001-0.33	0.001-0.008	0.004-0.33	0.01-0.69	0.001-0.33	0.001-0.01	0.001-0.33	0.01-0.69
		2	2.1	0.27-0.41	0.001-0.013	0.26-0.41	0.55-0.86	0.01-0.41	0.001-0.013	0.01-0.41	0.01-0.86
		3	2.1	0.08	0.000	0.08	0.17	0.08	0.00	0.08	0.08

YWS - Young Wallsend Seam
BHS - Borehole Seam
WBH - Wallsend Borehole Colliery Workings.

Calculation details of subsidence results presented are given in **Attachment A**.

6.0 Future Worst-Case Subsidence Contours

6.1 SPDS Model Development for the Minmi Site

Based on the supercritical subsidence predictions presented in **Section 5.3,** the **SPDS**® (Surface Deformation Prediction System - version 5.5R, May, 2007) model has been used to generate the predicted worst-case contours for subsidence, tilt, curvature, and strains.

SPDS® is a US developed (Virginia Polytechnical Institute) influence function model for making subsidence predictions above longwalls or pillar extraction panels. The model requires calibration to measured subsidence profiles for it to reliably predict the subsidence and differential subsidence profiles. Further details of the program are provided in **Appendix B**.

The model for Minmi has been developed using the following key subsidence profile parameters derived from the Newcastle Subsidence coalfield data provided in **ACARP, 2003**:

- The supercritical panel subsidence factor (S_{max}/T);
- Distance of the inflexion point (or maximum tilt location) from panel sides (d);
- Influence angle (β), which is defined by the angle (to the horizontal) from the inflexion point to the point of 'zero' or measurable subsidence (normally taken to be 20 mm);
- Angle of draw (θ), which is defined by the angle (to the vertical) from the panel edge to the point of 'zero' or measurable subsidence (normally taken to be 20 mm);
- The horizontal strain coefficient (β_s) is the linear constant used to estimate strain from the predicted curvature. It is equivalent to the reciprocal of the neutral axis of bending, d_n used in **ACARP, 2003**. Based on Newcastle Coalfield data, a value of $d_n = 10$ m or a $\beta_s = 0.1$ m^{-1} has been applied to predict 'smooth' profile strains using the **SPDS**® model curvatures.

The above input parameters determined for the Minimi site workings are summarised in **Table 4**.

Table 4 - Summary of the SPDS Model Input Parameters Used for the Minmi Subsidence Contour Predictions

Parameter	Units	Range
Maximum Panel Subsidence Factor, Smax/T	m/m	0.001 - 0.41
Panel Width, W	m	46 - 1072
Cover Depth, H	m	30 - 150
Panel W/H	m/m	0.5 - 7
Inflexion Point/Cover Depth Ratio, d/H	m/m	0.12 - 0.4
Inflexion Point Distance from Panel sides	m	12 - 48
Influence Angle (β)	degrees	47.5 - 58.1
tanβ	m/m	1.1 - 1.6
Angle of Draw (θ)	degrees	26.5
tanθ	m/m	0.5

The SPDS® model also uses a grid of cover depth points, which allows it to adjust the maximum panel subsidence when the panel widths are subcritical (i.e. W/H < 1.4).

6.2 Subsidence Contour Predictions

Subsidence contour predictions have been made for each seam by importing the Zone 1 to 3 panels in .dxf format into the **SPDS®** model and applying the appropriate subsidence profile values for each panel as previously discussed. The subsidence contours were then transformed into a 10 x 10 m grid in **Surfer8®** using data 'kriging' techniques. The grids were also given a light filter to reduce the artificial effect of grid 'noise' on the differential subsidence predictions.

The worst-case future subsidence contours for the BHS and YWS workings are presented in **Figures 8a** and **9a** for Pillar Run Case (i) and **Figure 11a** for Pillar Run Case (ii). *Note: The contours for the YWS panels did not change for Pillar Run Case (i) and (ii) due to the small Zone 2 areas in these workings.*

The multiple seam outcomes were determined by adding the contours for each seam together and are presented in **Figures 10a** and **12a** for Pillar Run Cases (i) and (ii) respectively.

The contours indicate that worst-case maximum subsidence will range from:

- 0.8 to 1.1 m above Zone 2 Pillar Panels in the BHS;
- 0.15 to 0.3 m above Zone 3 Panels in the BHS and YWS;
- <0.15 m above Zone 1 Pillars in both seams.

The location of the actual contours after a pillar run (if it occurs) will probably be somewhere between the predicted Pillar Run Cases (i) and (ii) contours.

6.3 Principal Tilt Contours

The maximum differential subsidence parameters were derived from the predicted subsidence contours using differential calculus techniques available in the **Surfer8®**.

The worst-case principle tilt contours for the BHS and YWS workings are presented in **Figures 8b** and **9b** for Pillar Run Case (i) and **Figure 11b** for Pillar Run Case (ii).

The multiple seam outcomes for tilt were determined from the multiple seam subsidence contours and are presented in **Figures 10b** and **12b** for Pillar Run Cases (i) and (ii) respectively.

A summary of the predicted ranges of maximum tilt for the Pillar Run Cases are shown in **Table 5**.

Table 5 - Predicted Maximum Tilts for Pillar Runs Cases (i) and (ii)

Pillar Run Case	Zone 2 Extraction Ratio (%)	Cover Depth to BHS Workings (m)	Maximum Tilt Range (mm/m)
(i) Complete Pillar Run in Zone 2	61 - 72	<30	14 - 17
		30 - 80	7 - 14
		80 - 150	2 - 7
(ii) Partial Pillar Run in Zone 2	72	<45	2 - 7
		45 - 80	7 - 14
		80 - 150	2 - 7
	61 - 65	<60	2 - 7
		60 - 80	7 - 12
		80 - 150	2 - 7

The maximum tilt in areas above Zones 1 and 3 are considered unlikely to be tilted by more than 3 mm/m, however, small areas with relatively stiff, standing pillars adjacent to or within low stiffness Zone 2 or 3 areas could also result in tilts with similar magnitudes as the values given in **Table 7** for the same depth of cover.

6.4 Principal Curvature Contours

The multiple seam outcomes for principle curvature were determined from the multiple seam subsidence contours and are presented in **Figures 10c** and **12c** for Pillar Run Cases (i) and (ii) respectively.

A summary of the predicted ranges of maximum tilt for the Pillar Run Cases are shown in **Table 6**.

Table 6 - Predicted Maximum Curvatures for Pillar Runs Cases (i) and (ii)

<table>
<tr><th>Pillar Run Case</th><th>Zone 2 Extraction Ratio (%)</th><th>Cover Depth to BHS Workings (m)</th><th>Maximum Curvature Range (1/km)</th><th>Minimum Curvature Radius Range (km)</th></tr>
<tr><td rowspan="3">(i) Complete Pillar Run in Zone 2</td><td rowspan="3">61 - 72</td><td><30</td><td>+/- 0.6</td><td>+/- 1.7</td></tr>
<tr><td>30 - 80</td><td>+/- 0.5</td><td>+/- 2.0</td></tr>
<tr><td>80 - 150</td><td>+/- 0.2</td><td>+/- 5.0</td></tr>
<tr><td rowspan="6">(ii) Partial Pillar Run in Zone 2</td><td rowspan="3">72</td><td><45</td><td>+/- 0.2</td><td>+/- 5.0</td></tr>
<tr><td>45 - 80</td><td>+/- 0.5</td><td>+/- 2.0</td></tr>
<tr><td>80 - 150</td><td>+/- 0.2</td><td>+/- 5.0</td></tr>
<tr><td rowspan="3">61 - 65</td><td><60</td><td>+/- 0.2</td><td>+/- 5.0</td></tr>
<tr><td>60 - 80</td><td>+/- 0.4</td><td>+/- 2.5</td></tr>
<tr><td>80 - 150</td><td>+/-0.2</td><td>+/- 5.0</td></tr>
</table>

All other areas with Zones 1 and 3 are likely to have curvatures of < 0.1 km-1 (>10 km radius), however, the presence of relatively stiff, standing pillars adjacent to or within low stiffness Zone 2 or 3 areas could also result in curvatures in with similar magnitudes as the values given in **Table 6** for the same depth of cover.

6.5 Principal Strain Contours

The multiple seam outcomes for principle horizontal strains (tensile and compressive) were determined from the multiple seam curvature contours and are presented in **Figures 10d** and **12d** for Pillar Run Cases (i) and (ii) respectively.

A summary of the predicted ranges of maximum tilt for the Pillar Run Cases are shown in **Table 6**.

Table 7 - Predicted Maximum Strains for Pillar Runs Cases (i) and (ii)

Pillar Run Case	Zone 2 Extraction Ratio (%)	Cover Depth to BHS Workings (m)	Maximum Horizontal Strain Range*+ (mm/m)
(i) Complete Pillar Run in Zone 2	61 - 72	<30	+/- 6
		30 - 80	+/- 5
		80 - 150	+/- 2
(ii) Partial Pillar Run in Zone 2	72	<45	+/- 2
		45 - 80	+/- 5
		80 - 150	+/- 2
	61 - 65	<60	+/- 2
		60 - 80	+/- 4
		80 - 150	+/-2

* - Tension is positive.
+ - Strain concentrations due to cracking of near surface rock can increase the predicted values locally by 2 times. Deep soil profiles tend to reduce the likelihood of strain magnification.

All other areas with Zones 1 and 3 are likely to have strains of < +/-1 mm/m, however, the presence of relatively stiff, standing pillars adjacent to or within low stiffness Zone 2 or 3 areas could also result in strains with similar magnitudes as the values given in **Table 7** for the same depth of cover.

6.6 Subsidence Impact Hazard Zones

Based on discussions with the MSB, the proposed development structure types will be mostly restricted by the potential maximum tilts that could develop if a pillar run occurs. The principal curvature and horizontal strain can usually be designed for by including an appropriate level of articulation or flexibility in the superstructure. As subsidence itself does not cause damage directly, it is only really used as an indicator of the tilt, curvature and strain magnitudes.

Predicted future tilts of > 7 mm/m represent a ‘high’ subsidence impact hazard as the buildings will be required to be re-levelled to remain serviceable.

Areas where the tilts could exceed this limit are shown as black line cross hatching in **Figures 10b** and **12b** for Pillar Run Cases (i) and (ii) respectively. Representative multi-seam subsidence and tilt profiles for Pillar Run Cases (i) and (ii) have also been prepared along Sections A and B (see **Figures 10a** or **12a** for their location) and are shown in **Figures 13** and **15** respectively.

The high tilt hazard zones have the potential to occur above the Zone 2 (partial extraction panels) in the BHS if the pillars are still standing and a pillar run develops at some point in the future. As previously discussed, Pillar Run Case (i) represents the scenario where the pillar run starts in the middle of the panel and goes right out to the panel sides. Pillar Run Case (ii) represents the scenario where the pillar run stops somewhere between the middle of the panel where the strength of the remnant coal pillars have sufficient strength to support the applied abutment loads. It has been assessed that the pillar runs could stop when the cover depth decreases to < 60 m for the 61-65% extraction ratio BHS panels and < 45 m for the 72% extraction ratio BHS panels.

Based on the tilt v. cover depth profiles across the site (see **Figures 14** and **16** for each pillar run case) and the associated predicted tilt contours (see **Figures 10b** and **12b),** the high tilt hazard areas will only affect the areas were cover depths are < 80 m, as a pillar run in the Zone 2 panels are unlikely to generate tilts that will exceed 7 mm/m where the cover depth is greater.

The tilt profiles also indicate that where a pillar run stops, a band of high tilt between 7 and 14 mm/m could develop over a 50 m wide area along the goaf side edge of the run ‘front’ (see also **Figures 13** and **15**).

The high hazard curvature and strain zones are shown for each Pillar Run Case in **Figures 10c and 10d** for Case (i) and **Figures 12c and 12d** for Case (ii).

Zones of ‘High’ curvature hazard have been indicated where curvatures could exceed 0.2 km^{-1} or a curvature radius of < 5 km.

Zones of ‘High’ strain hazard have been indicated where strains could exceed +/- 3 mm/m (with tension positive).

It is also important to note that local tilt, curvatures and strains that are similar in magnitude to the predicted values for the ‘High’ impact hazard areas could also develop anywhere on the site where there are stiff standing pillars adjacent to relatively softer workings areas that may consolidate if water levels continue to rise in the panels.

7.0 Conclusions

The study has identified several potential high subsidence impact hazard zones for the Minmi Site where tilts > 7 mm/m could develop above the old welsh bord pillars in the Borehole Seam. Maximum subsidence is estimated to range from 0.8 to 1.1 above these panels.

The high tilt hazard areas have been defined for two possible pillar run case scenarios, which have either ignored or included the FoS of the pillars under full tributary area and abutment load conditions. Pillar Run Case (i) assumes the pillar run will occur right out to the panel limits and ignores the potential strength of the remnant pillars to support the applied abutment loads.

Pillar Run Case (ii) assumes that the pillar run will stop where pillar FoS is greater than 2.11 under FTA loading or > 1.6 under the assessed abutment loading conditions likely to be present along the goaf edges or pillar run ‘front’. It is assessed that Pillar Run Case (ii) represents the more likely outcome as the worst-case scenario.

Areas above the BHS workings where a pillar run occurs and the depth of cover is > 80 m, are considered unlikely to develop tilts of more than 7 mm/m because of the cover depth and less severe subsidence profile that will develop.

Maximum curvatures in the potential pillar run areas are estimated to range from +/- 0.3 to 0.6 km^{-1} (or radii of 1.7 to 3.33 km). Maximum strains associated with the pillar run curvatures are estimated to range between 3 and 5 mm/m.

Tilt, curvature and strain hazards will probably also exist in areas were 150 to 300 mm of subsidence is predicted above old goafs, although the likelihood that the tilts will exceed 7 mm/m, curvatures greater than 0.2 km^{-1} and strains in excess of 2 mm/m is very low.

It is considered likely that all the proposed buildings in the study area are likely to require articulation and subsidence impact amelioration details to be included in the design of the superstructure of the proposed buildings. Further discussions with the MSB in regards to appropriate building design constraints are recommended.

The locations of the high subsidence, tilt, curvature, and strain zones have been indicated in this report for subsequent assessment of appropriate building development constraints.

The design of driveways, retaining walls and site infrastructure (i.e. roads, drainage, sewerage and utilities) should also consider the worst-case subsidence contours presented herein.

8.0 References

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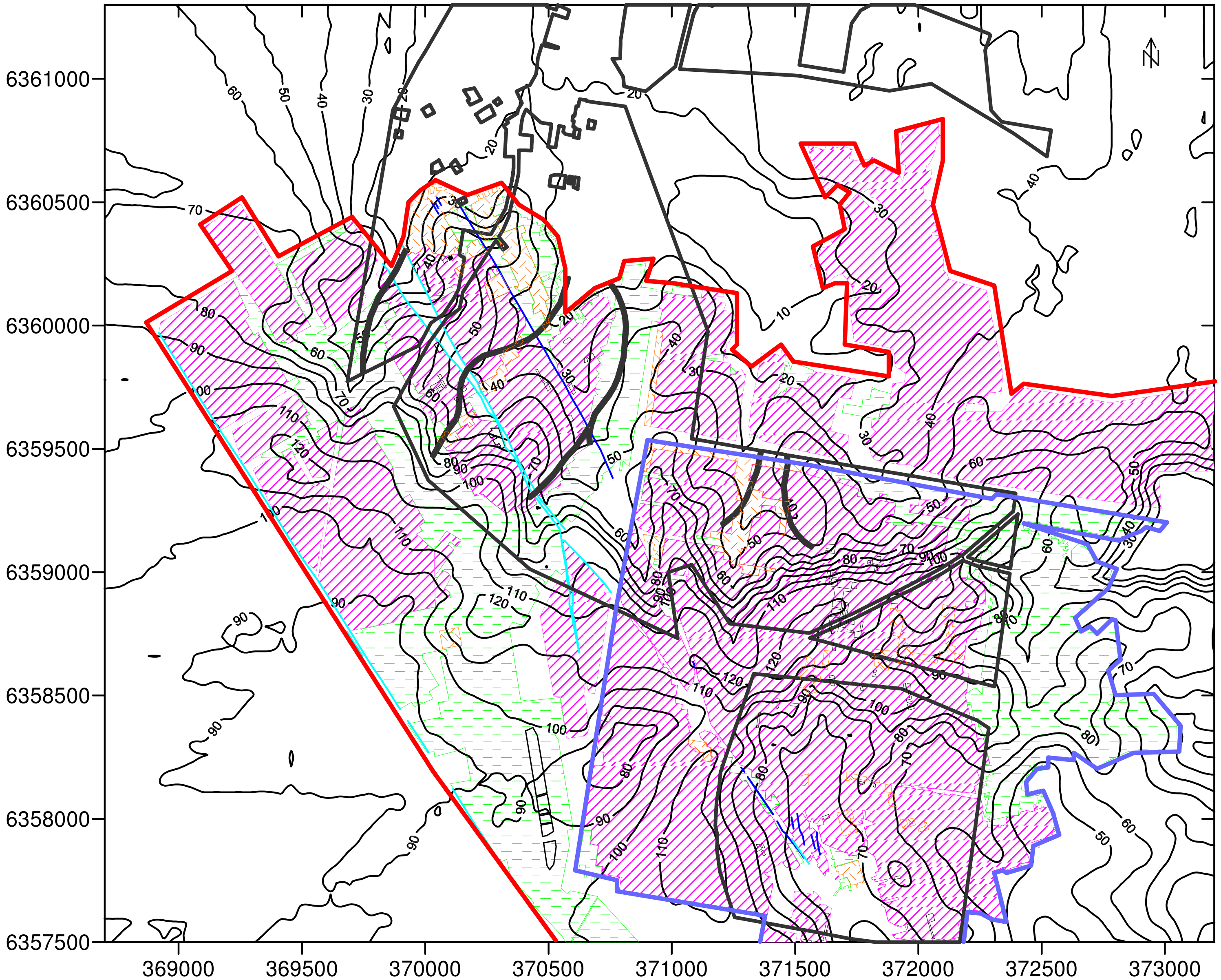
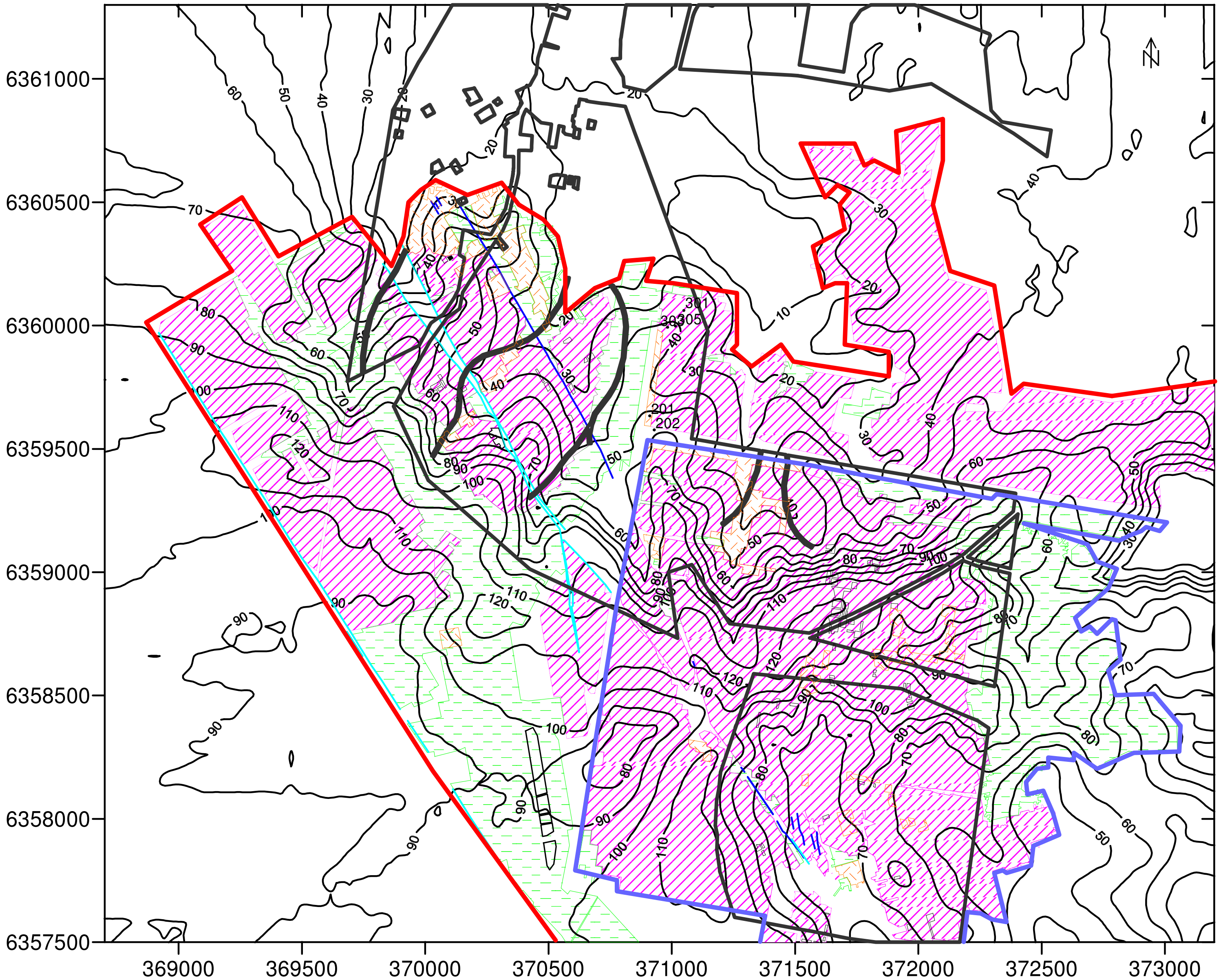


Key

- Wallsend Borehole Colliery
- Gretley Colliery
- Mine Workings Limits (>85% Extraction)
- Mine Workings Limits (40-50% Extraction)
- Mine Workings Limits (20-35% Extraction)
- Remnant Pillars of Potential Significance
- Site Boundary
- Normal Fault
- Igneous Dyke (Very High Strength

DgS	Engineer: S.Ditton	Client:	Douglas Partners DPS-002/1
	Drawn: S.Ditton		
	Date: 09.11.07	Title:	Cover Depth Contours above the Pillar Extraction Panels in the Young Wallsend Seam (Wallsend Borehole and Gretley Collieries)
	Ditton Geotechnical Services Pty Ltd	Scale:	1:25,000 — Figure No: 1



Key

- Wallsend Borehole Colliery
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- Mine Workings Limits (>85% Extraction)
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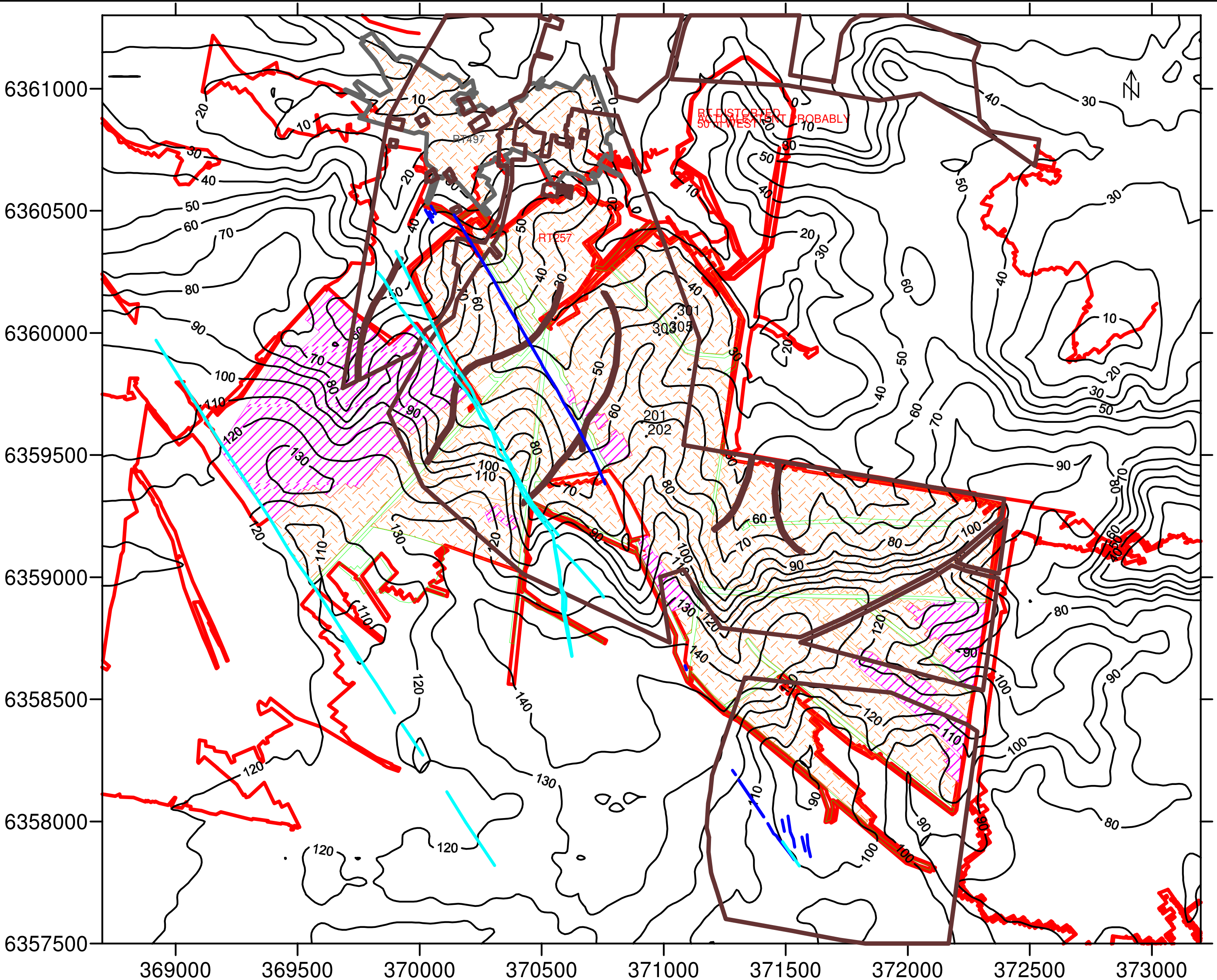
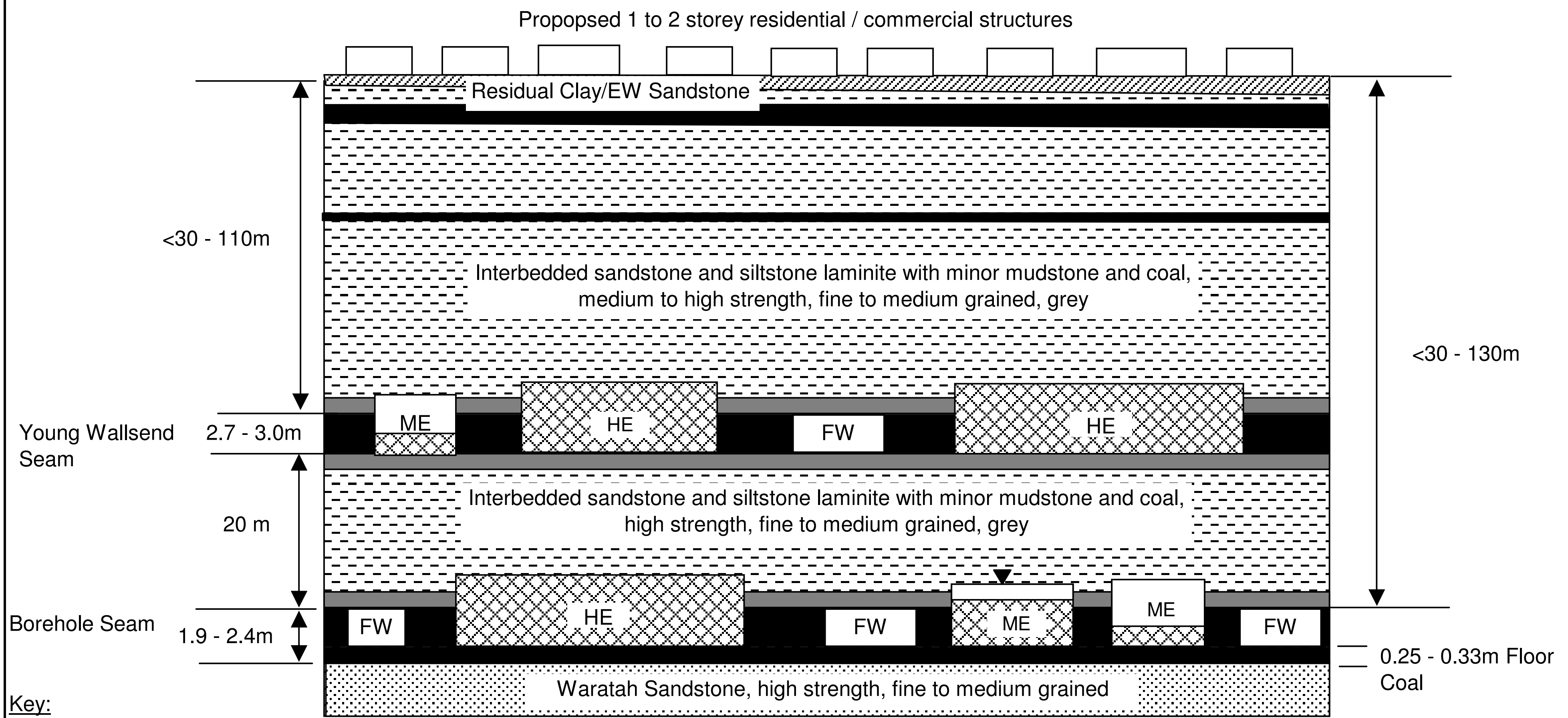
	Date: 09.11.07	Title:	Cover Depth Contours above the Pillar Extraction Panels in the Young Wallsend Seam (Wallsend Borehole and Gretley Collieries)
	Ditton Geotechnical Services Pty Ltd	Scale:	1:25,000 — Figure No: 1



Key

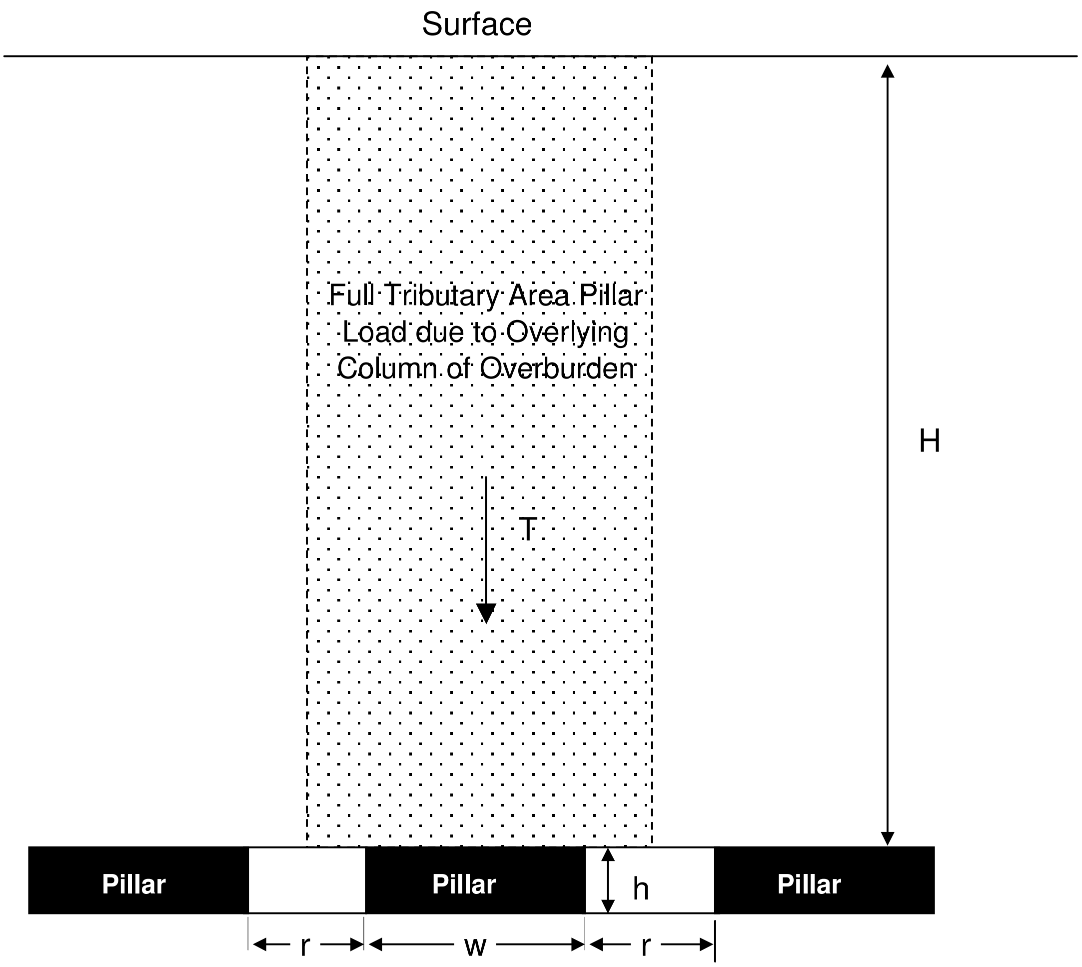
- Browns Minmi - A,B&C Pits (RT497)
- Duckenfield No.1 & No.2 (256, 257 & 257A)
- Mine Workings Limits (>85% Extraction)
- Mine Workings Limits (50-75% Extraction)
- Mine Workings Limits (20-40% Extraction)
- Site Boundary
- Normal Fault
- Igneous Dyke (Very High Strength

DgS	Engineer: S.Ditton	Client:	Douglas Partners DPS-002/1
	Drawn: S.Ditton		
	Date: 09.11.07	Title:	Cover Depth Contours above the Pillar Extraction Panels in the Borehole Seam (Browns & Duckenfield Collieries)
	Ditton Geotechnical Services Pty Ltd	Scale:	1:25,000 — Figure No: 2



Key:
FW - First Workings (e = 15 - 45%)
ME - Moderate Second Workings (e = 50 - 60% in YW Seam; 61 - 72% in BH Seam)
HE - High Extraction (e = 80 - 85%)

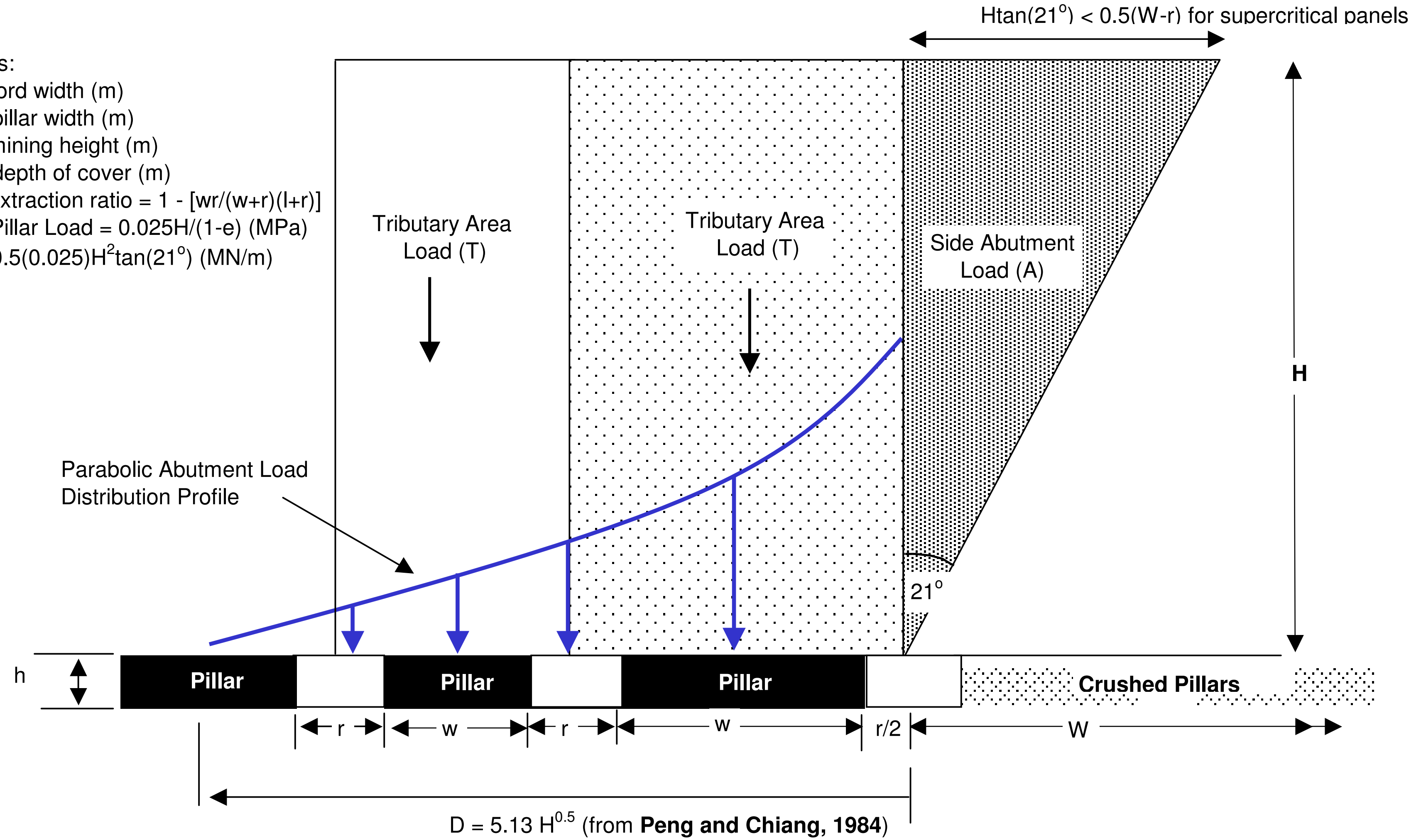
DgS	Engineer:	S.Ditton	Client:	Douglas Partners Pty Ltd
	Drawn:	S.Ditton		DPS-002/1
	Date:	25.07.08	Title:	Overburden Conditions Beneath the Minmi Site
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS Figure No: 3



Notes:
- r = bord width (m)
- w = pillar width (m)
- h = mining height (m)
- H = depth of cover (m)
- e = extraction ratio = 1 - [wr/(w+r)(l+r)]
- T = Pillar Load = 0.025H/(1-e) (MPa)

Engineer:	S.Ditton	Client:	Douglas Partners Pty Ltd		
Drawn:	S.Ditton		DPS-002/1		
Date:	28.07.08	Title:	Conceptual Model of Full Tributary Area Loading Acting on Pillars Beneath the Site		
Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No:	4

Notes:
r = bord width (m)
w = pillar width (m)
h = mining height (m)
H = depth of cover (m)
e = extraction ratio = 1 - [wr/(w+r)(l+r)]
T = Pillar Load = 0.025H/(1-e) (MPa)
A = $0.5(0.025)H^2\tan(21^\circ)$ (MN/m)



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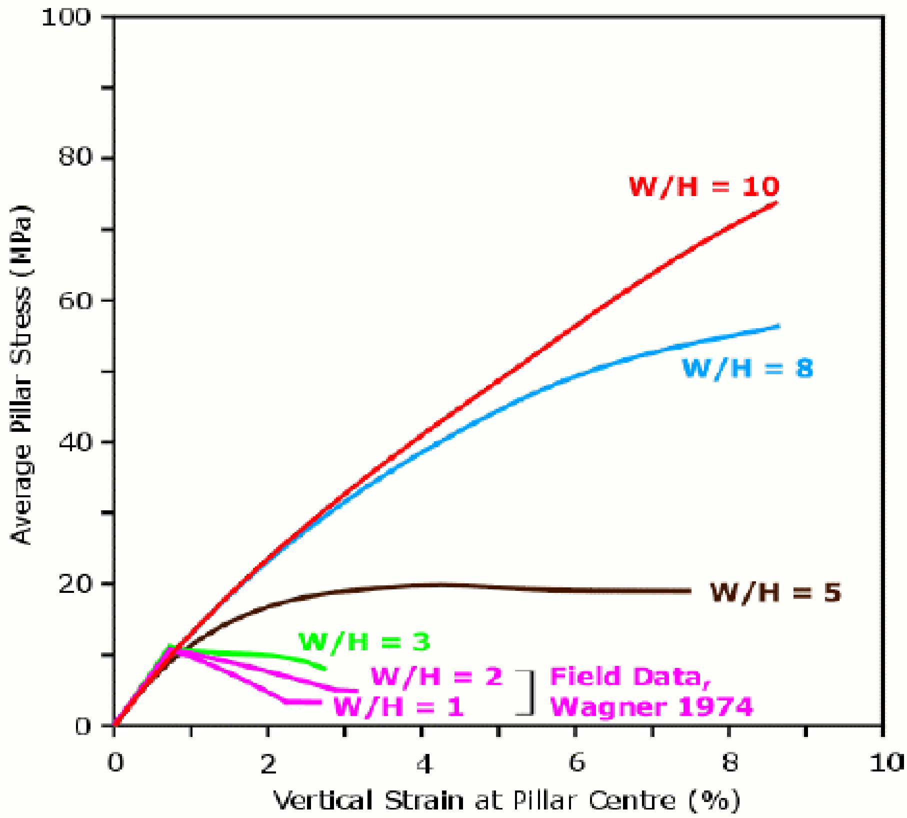
	Drawn: S.Ditton		
	Date: 28.07.08	Title:	Conceptual Model of Abutment Load Acting on Site Pillars Due to Pillar Run Scenario
	Ditton Geotechnical Services Pty Ltd	Scale:	NTS — Figure No: 5



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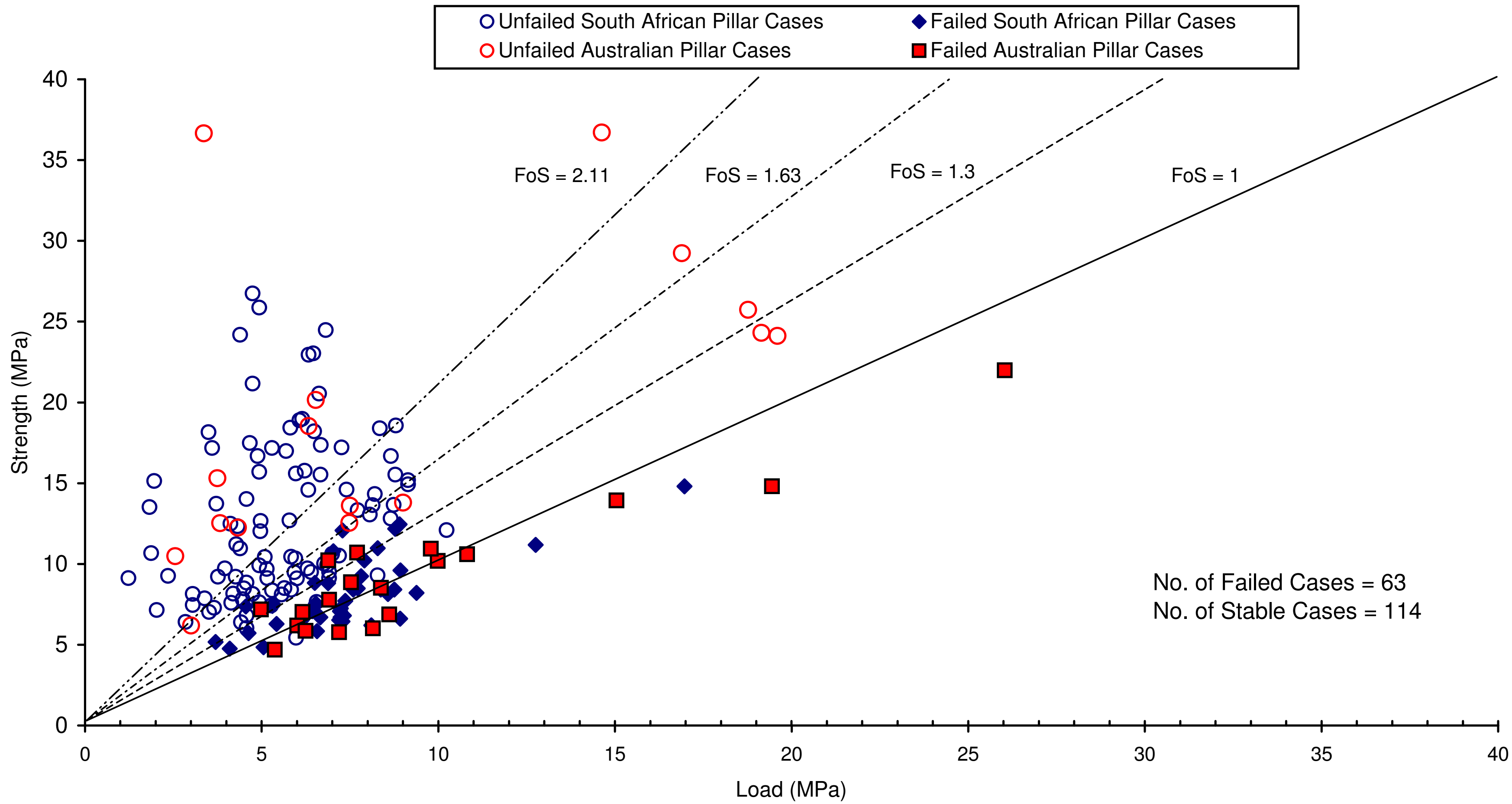
	Drawn:	S.Ditton		DPS-002/1		
	Date:	28.07.08	Title:	In-situ Pillar Stress v. Strain Behaviour for a Range of Pillar Width/Height Ratios		
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No:	6



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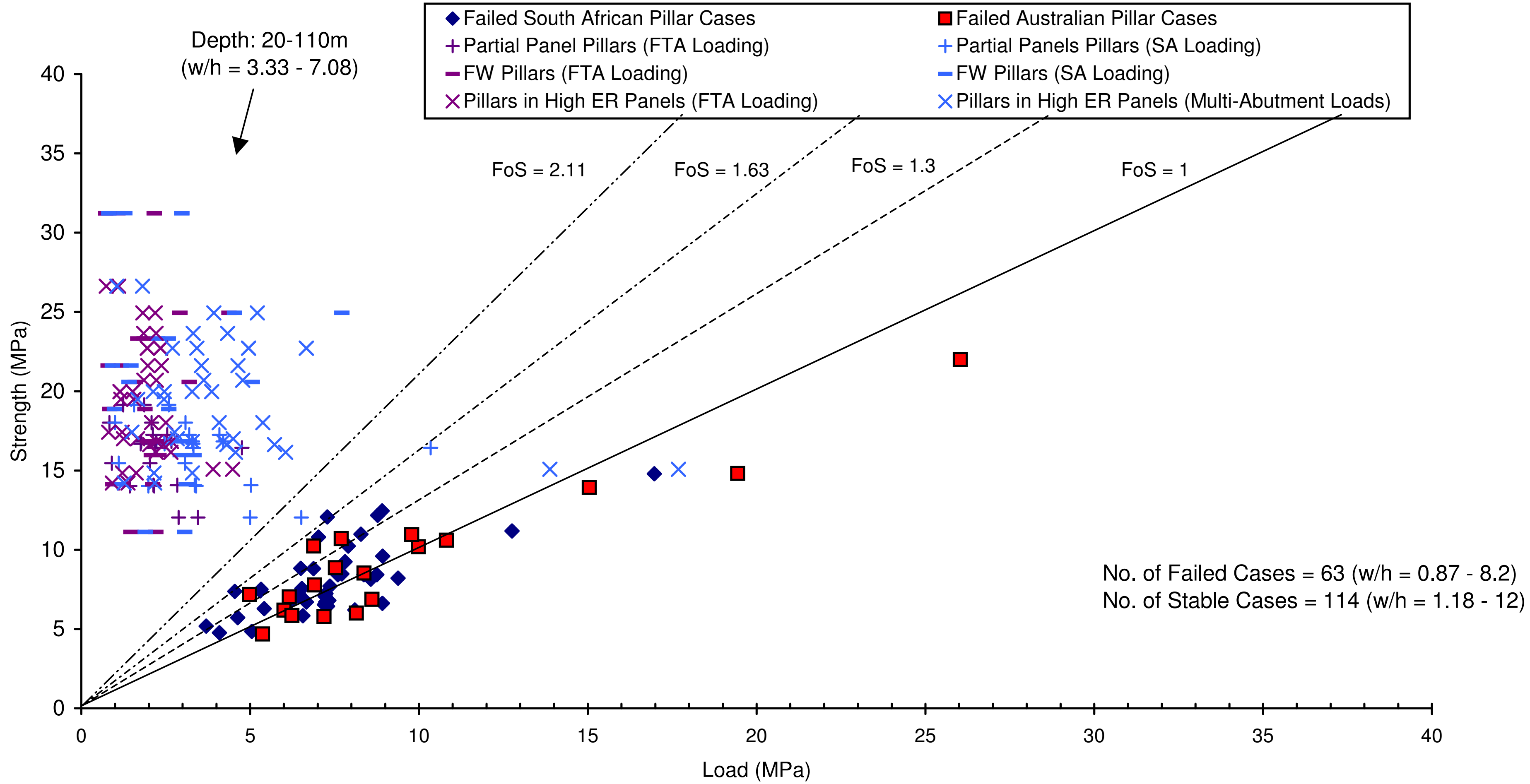
	Drawn: S.Ditton			
	Date: 06.12.07	Title:	Database of Failed and Stable Bord and Pillar Panels from Australian and South African Coal Mines	
	Ditton Geotechnical Services Pty Ltd	Scale:	NTS	Figure No: 7a



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DgS	Engineer: S.Ditton		Client:	Douglas Partners Pty Ltd DPS-002/1
	Drawn: S.Ditton			
	Date: 06.12.07		Title:	Database of Failed and Stable Bord and Pillar Panels from Australian and South African Coal Mines and Wallsend Borehole Pillars in Young Wallsend Seam Workings at Minmi
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS
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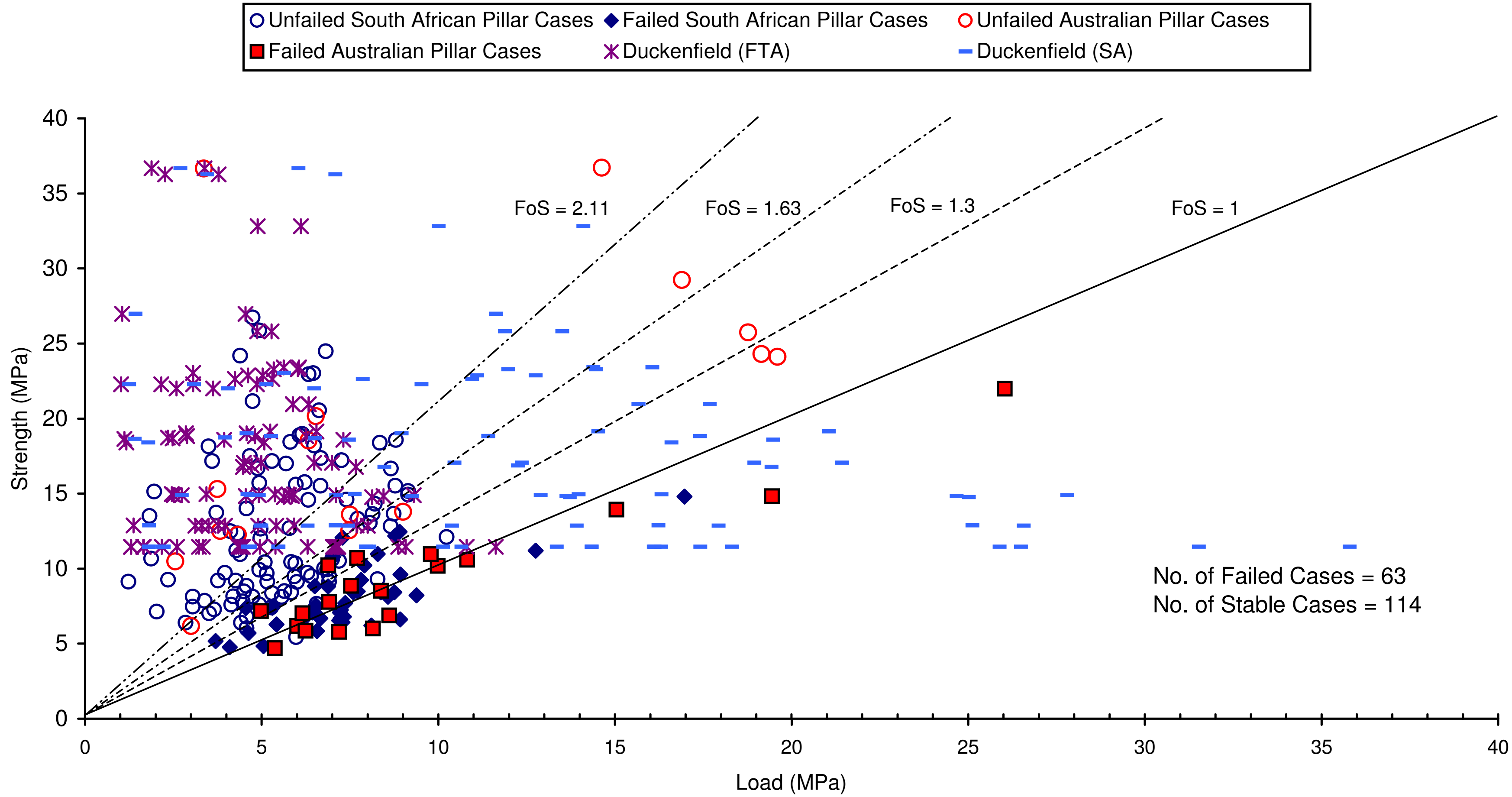

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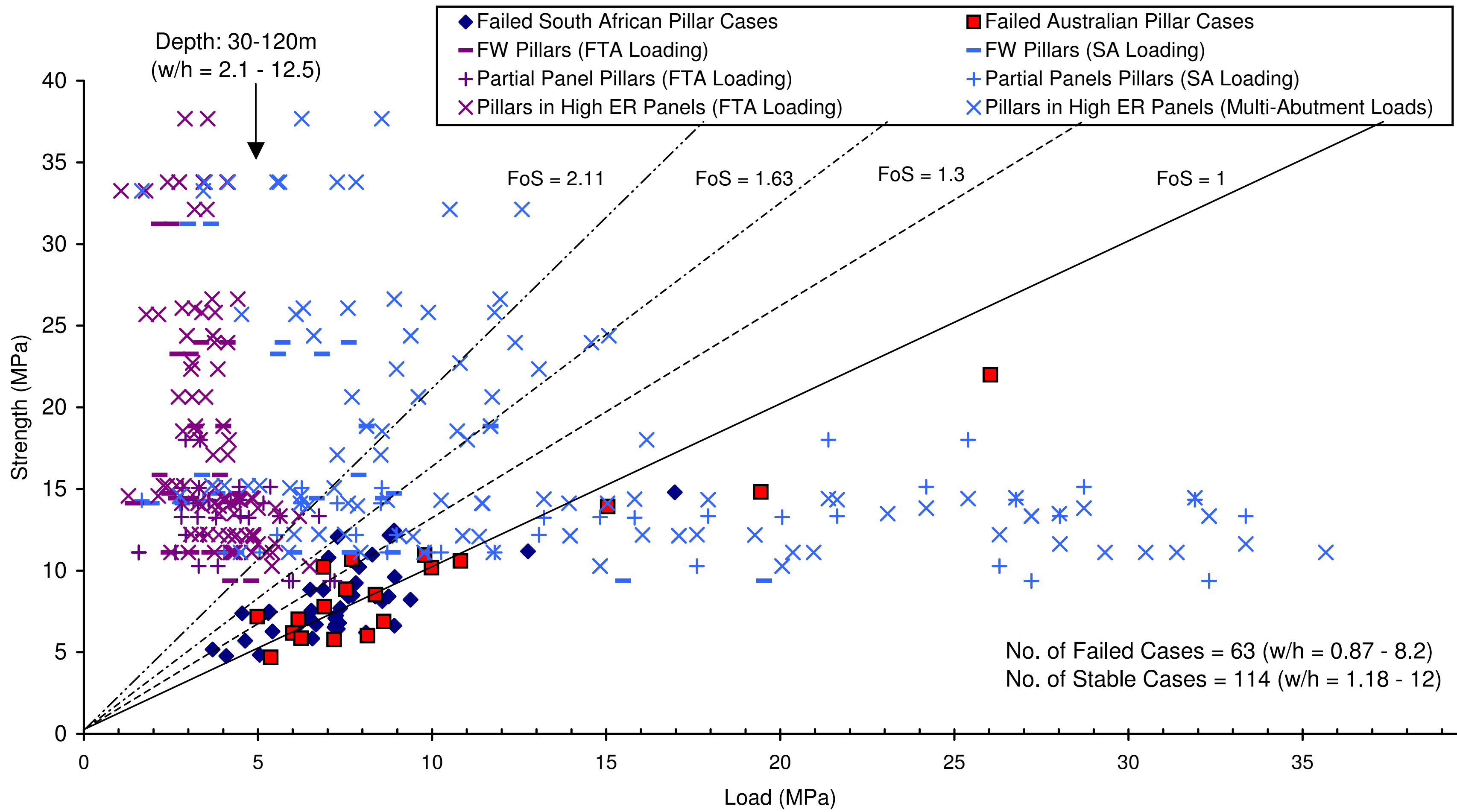
DgS	Engineer: S.Ditton		Client:	Douglas Partners Pty Ltd DPS-002/1
	Drawn: S.Ditton			
	Date: 06.12.07		Title:	Database of Failed and Stable Bord and Pillar Panels from Australian and South African Coal Mines and Borehole Seam Workings (Duckenfield) Pillars at Minmi
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS — Figure No: 7c



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	Ditton Geotechnical Services Pty Ltd		Scale:	NTS
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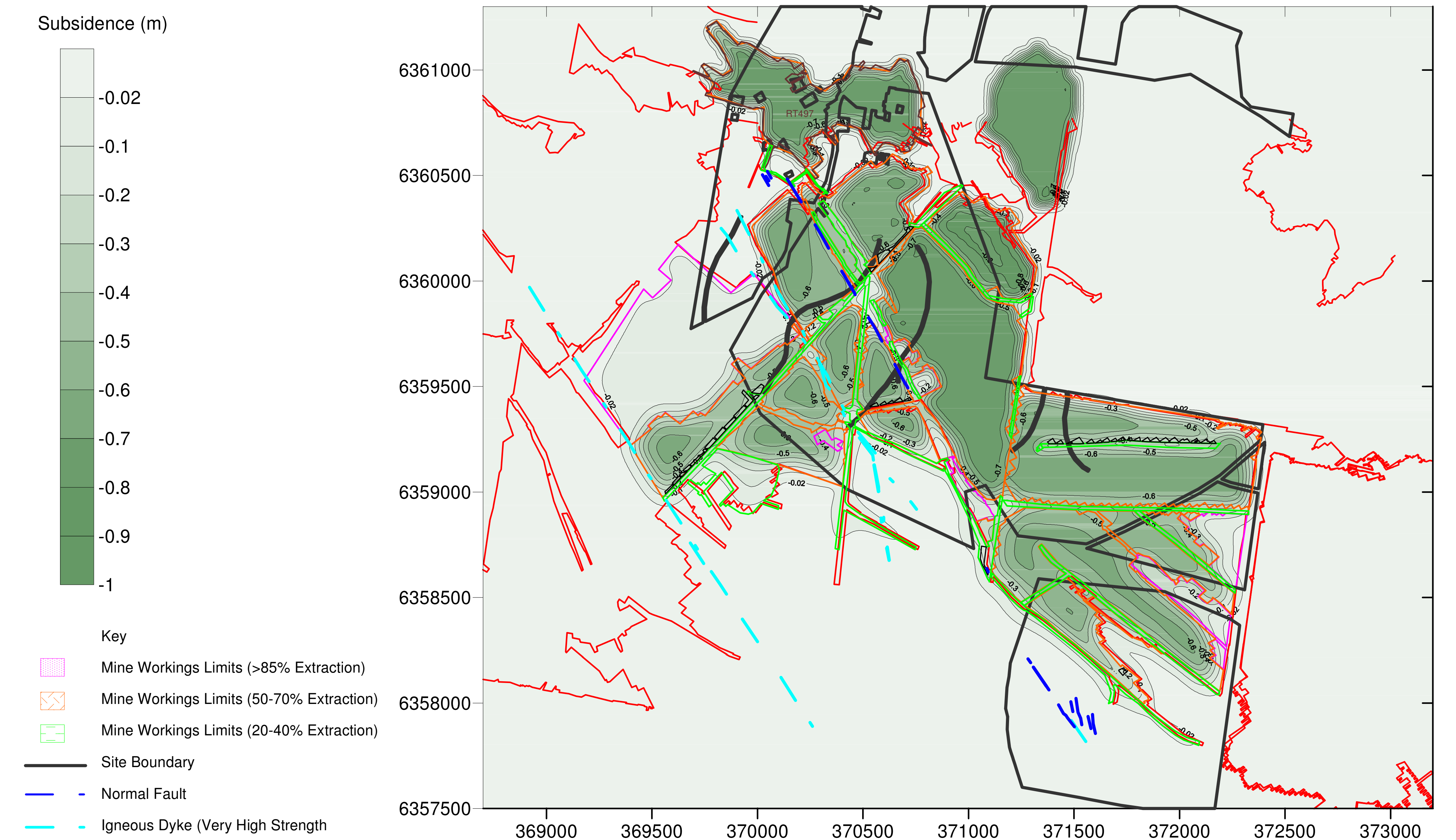

DgS	Engineer: S.Ditton	Client:	Douglas Partners DPS-002/1
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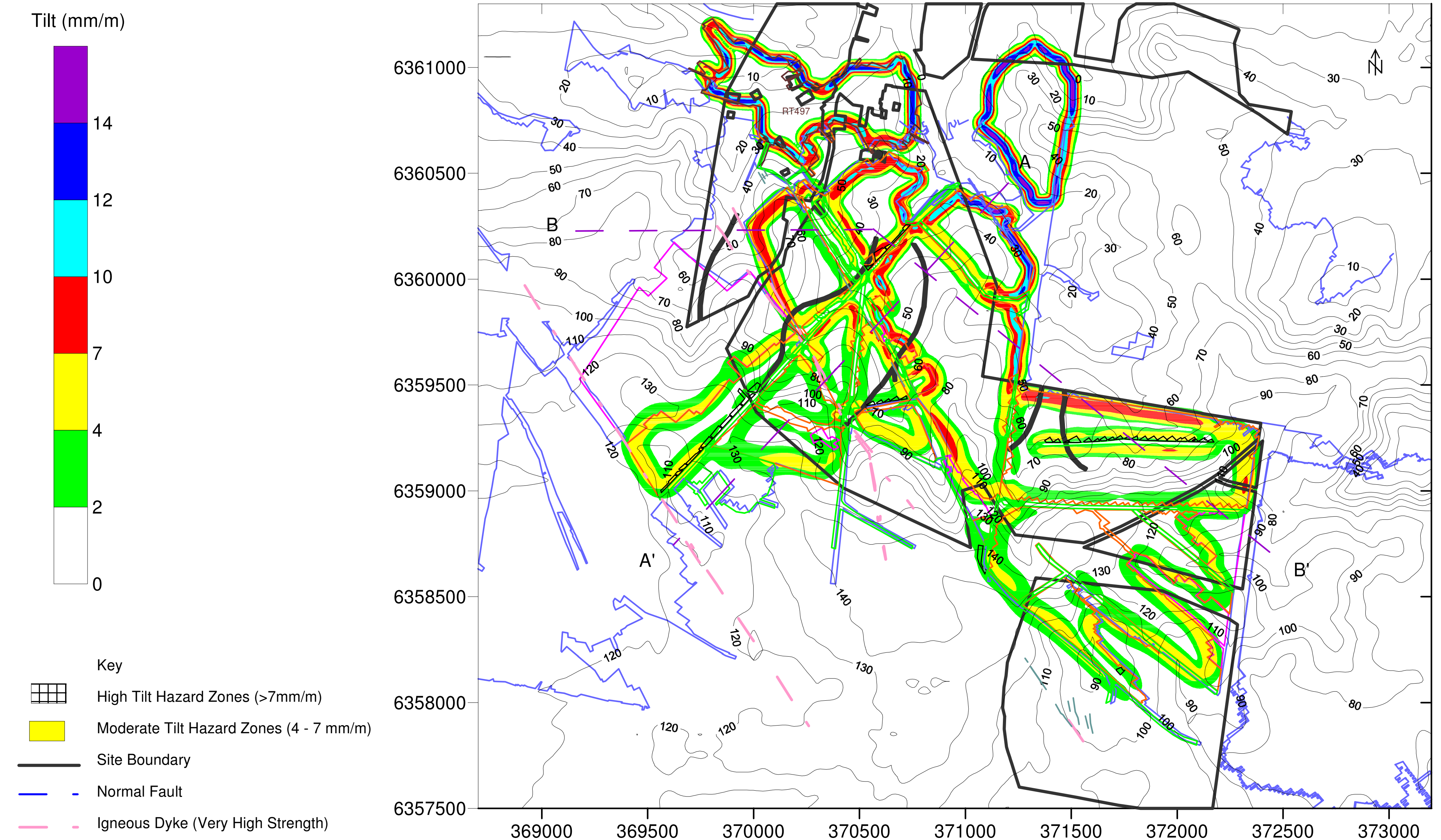
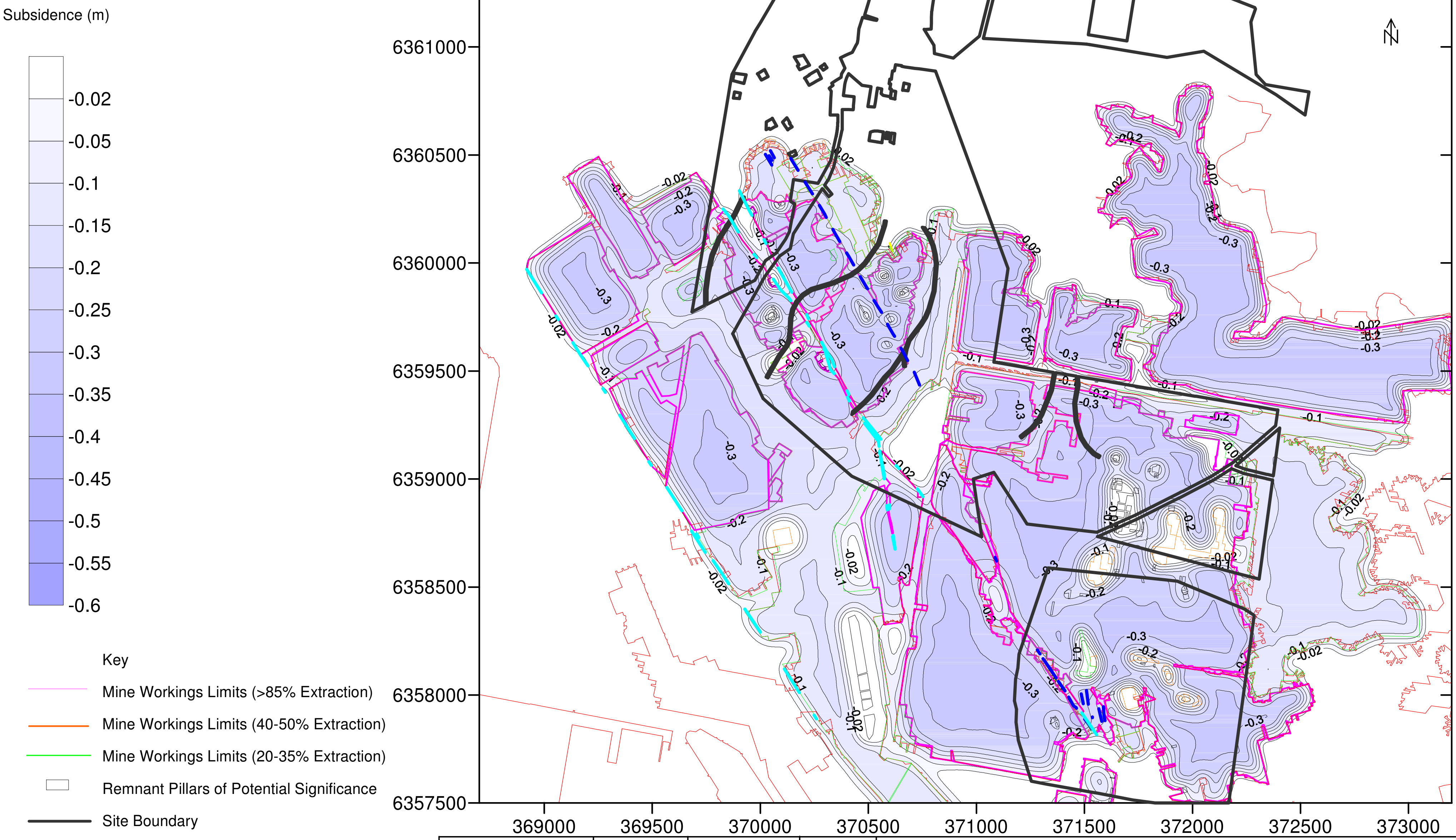
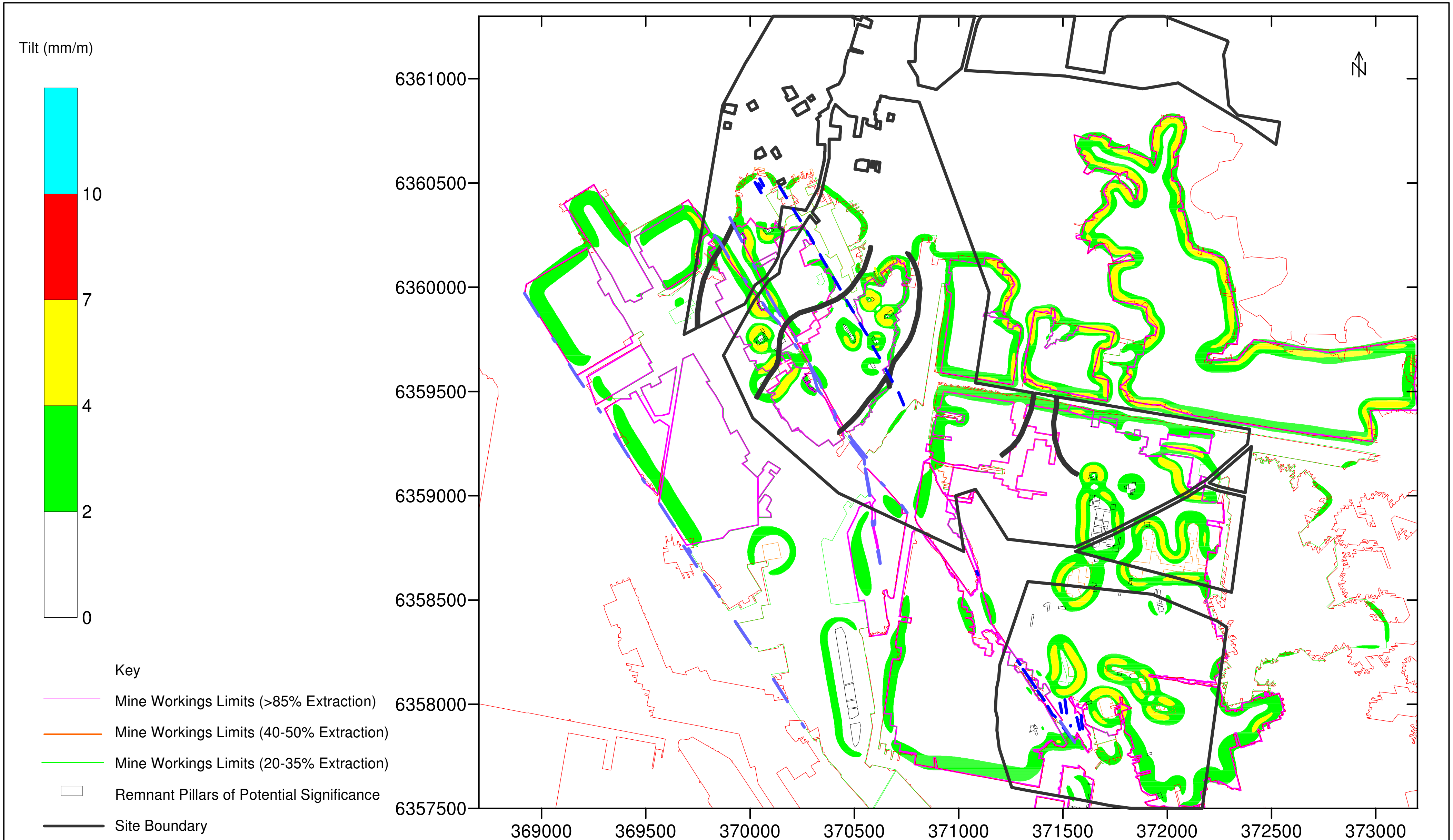
Ditton Geotechnical Services Pty Ltd		Scale:	1:25,000
		Figure No:	8a



DgS Ditton Geotechnical Services Pty Ltd	Engineer:	S.Ditton	Client:	Douglas Partners DPS-002/1
	Drawn:	S.Ditton	Title:	Worst-case Future Tilt Contours above the Pillar Extraction Panels in the Borehole Seam (Browns & Duckenfield) with Pillar FoS for the FTA Load Case Ignored
	Date:	17.07.08		
			Scale:	1:25,000 — Figure No: 8b

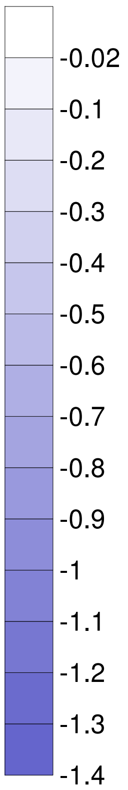


DgS	Engineer:	S.Ditton	Client:	Douglas Partners DPS-002/1
	Drawn:	S.Ditton		
	Date:	29.11.07	Title:	Predicted Future Worst-Case Subsidence Contours for the Pillar Extraction Panels in the Young Wallsend Seam (Wallsend Borehole and Gretley Collieries)
Ditton Geotechnical Services Pty Ltd			Scale:	1:25,000
			Figure No:	9a



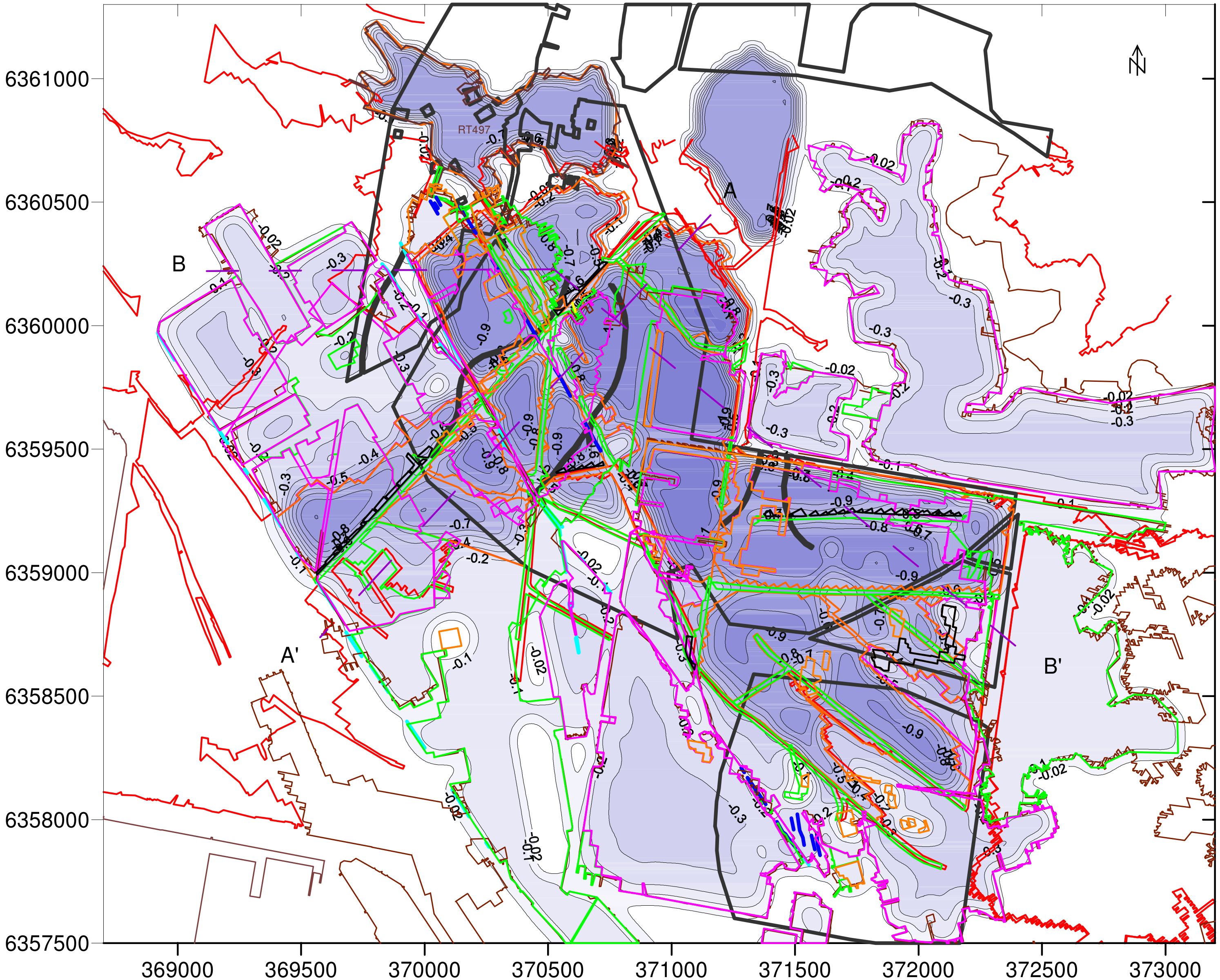
DgS Ditton Geotechnical Services Pty Ltd	Engineer:	S.Ditton	Client:	Douglas Partners DPS-002/1		
	Drawn:	S.Ditton				
	Date:	29.11.07	Title:	Predicted Future Worst-Case Tilt Contours for the Pillar Extraction Panels in the Young Wallsend Seam (Wallsend Borehole and Gretley Collieries)		
			Scale:	1:25,000	Figure No:	9b

Subsidence (m)



Key

- Mine Workings Limits (>85% Extraction)
- Mine Workings Limits (50-70% Extraction)
- Mine Workings Limits (20-40% Extraction)
- Site Boundary
- Normal Fault
- Igneous Dyke (Very High Strength
- Extent of Browns-Minmi & Duckenfield Mines
- Extent of Wallsend Borehole & Gretley Mines



Engineer:	S.Ditton	Client:	Douglas Partners DPS-002/1
Drawn:	S.Ditton		
Date:	29.11.07	Title:	Predicted Future Worst-case Subsidence Contours above the Pillar Extraction Panels in the Borehole Seam and Young Wallsend Seam if Pillar FoS under FTA Load Case is Ignored
Ditton Geotechnical Services Pty Ltd		Scale:	1:25,000
		Figure No:	10a